

- Stein, L., Xue, B. G., & Belluzzi, J. D. (1993). A cellular analogue of operant conditioning. *Journal of the Experimental Analysis of Behavior*, 60, 41–53.
- Stein, L., Xue, B. G., & Belluzzi, J. D. (1994). In vitro reinforcement of hippocampal bursting: A search for Skinner's atoms of behavior. *Journal of the Experimental Analysis of Behavior*, 61, 155–168.
- Westenbroek, R. E., Ahljianian, M. K., & Catterall, W. A. (1990). Clustering of L-type Ca^{2+} channels at the base of major dendrites in hippocampal pyramidal neurons. *Nature*, 347, 281–284.
- Wong, R. K. S., & Prince, D. A. (1978). Participation of calcium spikes during intrinsic burst firing in hippocampal neurons. *Brain Research*, 159, 385–390.

MELIORATION AND CONTIGUITY

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Donahoe, Palmer, and Burgos make a number of arguments: Molar relations should be understood as the outcome of local processes; reinforcement is not simply the strengthening of responses but also involves the stimuli present at that time; operant and classical conditioning are not distinct, but are separated only on the basis of what kinds of events are reliably present when reinforcement is presented; modeling (in this case by means of a neural network) can be productive in terms of integrating a number of behavioral phenomena.

A number of these issues tie in with an account of melioration (Herrnstein & Vaughan, 1980) in terms of strengthening by contiguity. Consistent with Donahoe et al., I believe that it is possible to derive melioration from the more basic processes advocated by Skinner. In an experiment using concurrently available alternatives, an alternative can gain value by pairing with reinforcement, whether the reinforcement is response produced or not (e.g., using concurrent variable-time [VT] VT schedules and only requiring a changeover response); time spent without reinforcement in the presence of that alternative drives its value toward zero. From these assumptions,

one can deduce that the value of an alternative is a strictly monotonically increasing function of rate of reinforcement in its presence. Given two or more such alternatives, changeover responses can then be viewed as increasing or decreasing in strength, depending on whether they make a transition from a lower to a higher, or from a higher to a lower, situation. This strengthening model (presented in Vaughan, 1982), in a nutshell, allows one to deduce the process of melioration, and in turn account for behavior on concurrent variable-interval (VI) VI, concurrent VI variable-ratio (VR), and concurrent VR VR schedules. The fact that a changeover delay is often required to prevent rapid alternation, with a duration similar to the duration of unsignaled delays that will reduce responding to a low level (Williams, 1976), suggests that the strength of changeovers is being maintained by the transitions from one conditioned reinforcer to another, rather than by food presentations on the alternative being changed to.

On the other hand, Donahoe et al.'s argument that operant and classical conditioning are the same processes, distinguished only by what event is reliably contiguous with reinforcement, may require some modification. For example, consider the Rescorla-Wagner model (Rescorla & Wagner, 1972),

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which states that the presentation of a reinforcer changes the value of stimuli present:

$$\Delta V_A = \alpha_A \beta_1 (\lambda_1 - V_{AX}) \quad (1)$$

Here, ΔV_A is the change in value of Stimulus A, α_A is a measure of the salience of A, β_1 is a rate parameter related to this reinforcer, λ_1 is the asymptotic level that the value of A can reach, and V_{AX} is the current value of A along with background Stimulus X. Let me first suggest a slightly simpler form of Equation 1:

$$\Delta V_A = f(V_B - V_A). \quad (2)$$

Here, V_A is the value of Stimulus A, and V_B is the value of reinforcement (the stimulus paired with A). In the case of the Rescorla-Wagner model, this is the value of all stimuli present when reinforcement occurs. That property (along with α and β) could be incorporated into Equation 2 but would serve no useful purpose here. The function f is simply assumed to be strictly monotonically increasing, with $f(0) = 0$.

If a pigeon pecks a key and there are no transitions, extinction takes place. For simplicity, one may assume one form of equation for both classical and operant extinction, which operates in the absence of transitions, but only while Stimulus (or Response) C is present:

$$dV_C/dt = f(V'_C - V_C). \quad (3)$$

Here, V'_C is what may be called the unconditioned value of Stimulus or Response C. In the case of a keylight or pecking a lighted key, V'_C is assumed to equal approximately zero, whereas in the case of food or a response whose operant level is above zero it would be positive; for shock it would be negative. If a pigeon is responding on two keys alternately, only the key currently being pecked is assumed to be governed by Equations 2 and 3; the other is not considered to be present. In this case there are also two other classes of responses, changeovers from Side A to Side B and changeovers in the opposite direction.

Suppose one wants to generalize Equation 2 to account for strength of responding. One might hypothesize an equation analogous to Equation 2, letting V_{RA} represent the value of a response during Stimulus A:

$$\Delta V_{RA} = f(V_B - V_{RA}). \quad (4)$$

Assume that a response with positive value

(or strength) occurs with some frequency that is a monotonic function of that strength, and that responses with zero or less than zero strength do not occur. It turns out that there are data that Equation 4 cannot handle. Dinsmoor (1962), for example, found that rats responded to escape a stimulus correlated with shocks and produced one not correlated with shocks. If V_{RA} is the value of responding and V_B is the value of the stimulus without shocks, such an equation would not predict any increase in the value of responding above zero, because the value of the stimulus produced by a response is zero. Consider now:

$$\Delta V_{RA} = f[(V_B - V_A) - V_{RA}]. \quad (5)$$

According to Equation 5, if Response RA is contiguous with a transition from Stimulus A to Stimulus B and there is a change in value upon making that transition, then the value of Response RA will approach the magnitude of that *change* in value, $V_B - V_A$, rather than the magnitude of the value of the stimulus being changed to. In Dinsmoor's (1962) experiment, for example, Stimulus A would have negative value, due to its pairings with shock (as a result of Equation 2). A response would produce a transition from A to B, a stimulus without shocks, and the value of that transition would be positive. Response RA, then, would gain positive value due to being contiguous with that positive transition.

By this account, then, classical and operant conditioning are closely related but distinct processes. It is logically possible that Equations 2 and 3 account for the value of a stimulus paired with reinforcement, and Equation 5 (in conjunction with Equation 3) accounts for the value of a response paired with a transition from one situation to another.

This conception is similar to that of Baum (1973), who treated reinforcement and punishment as cases of "situation transition." According to Baum (p. 151), reinforcement consists in the transition from a lower valued situation to a higher valued one, and punishment is a transition in the opposite direction. This analysis differs from his in that situations are assumed to gain and lose value by a process of classical conditioning, such as Equations 2 and 3 specify; Baum assumed that situations had no hedonic value but only discriminative values.

This local analysis of melioration is largely consistent with the position of Donahoe et al. Like theirs, this approach treats strength of responding as part of the three-term contingency. On the other hand, this analysis assumes two equations for learning, one for classical and one for operant behavior. Perhaps Equation 5 could be generalized to cover classical conditioning, in which case we would be back to a single process, but the equation would represent a break from the Rescorla–Wagner model.

REFERENCES

- Baum, W. M. (1973). The correlation-based law of effect. *Journal of the Experimental Analysis of Behavior*, 20, 137–153.
- Dinsmoor, J. A. (1962). Variable-interval escape from stimuli accompanied by shocks. *Journal of the Experimental Analysis of Behavior*, 5, 41–47.
- Herrnstein, R. J., & Vaughan, W., Jr. (1980). Melioration and behavioral allocation. In J. E. R. Staddon (Ed.), *Limits to action* (pp. 143–176). New York: Academic Press.
- Rescorla, R. A., & Wagner, A. R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A. H. Black & W. F. Prokasy (Eds.), *Classical conditioning: II. Current research and theory* (pp. 64–99). New York: Appleton-Century-Crofts.
- Vaughan, W., Jr. (1982). Choice and the Rescorla–Wagner model. In M. L. Commons, R. J. Herrnstein, & H. Rachlin (Eds.), *Quantitative analyses of behavior: Vol. 2. Matching and maximizing accounts* (pp. 263–279). Cambridge, MA: Ballinger.
- Williams, B. A. (1976). The effects of unsignalled delay of reinforcement. *Journal of the Experimental Analysis of Behavior*, 26, 441–449.

WHAT IS LEARNED?
REVISITING AN OLD ISSUE

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The authors of this provocative article argue that an S-R approach to behavior is an implicit assumption of connectionist network models of behavior. More exactly, their S-R model is better depicted as an S-O-R model, because a large part of variability in behavior comes not from variation in the stimulus input but from differences in activity, including spontaneous activity, between the nodes of the intervening network. As the authors make clear, these assumptions make it difficult to distinguish their S-R account from the traditional operant analysis in terms of the three-term contingency.

Although the authors make clear that their

type of S-R analysis does not necessarily require a causal explanation of behavior in terms of the particular stimulus that elicits each response, their approach does share with other S-R approaches (e.g., Thorndike, Hull) the assumption that the function of the reinforcer is to provide catalysis of S-R associations but not to enter into the associative relation itself. Donahoe et al.'s model utilizes the release of dopamine as the agent that increases the connection weights between different elements of the network. This so-called reinforcer, like the reinforcer in traditional S-R theory, remains outside of the associative network.

A critical issue posed for Donahoe et al. is whether a satisfactory model of conditioning can be constructed that omits any role for response–reinforcer associative relations. Al-

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